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EDGEWOOD ARSENAL
TECHNICAL REPORT

EATR 4434

THERMOREGULATORY RESPONSES OF BABOONS EXPOSED TO HEAT STRESS AND SCOPOLAMINE

by

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August 1970

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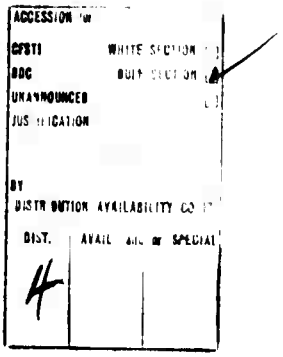

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FOREWORD

The work described in this report was authorized under Project 1B061102B71A, Life Sciences Basic Research in Support of Materiel (U). The work was started in October 1968 and completed in June 1969.

In conducting the research described in this report, the investigators adhered to the "Guide for Laboratory Animal Facilities and Care," as promulgated by the Committee on the Guide for Laboratory Animal Resources, National Academy of Sciences National Research Council.

Acknowledgments

The authors would like to thank Dr. F. N. Craig for his cooperation and helpful suggestions, and W. V. Blevins, C. R. Bulette, and H. L. Froehlich for technical assistance. The authors especially wish to thank Dr. W. D. Wagman, whose proposed study of the effects of heat stress and anticholinergic agents on complex behavior was the genesis of the present work. We would also like to express our appreciation to Mrs. Marion P. Royston for her aid in preparation of the manuscript.

DIGEST

The objects of this study were: (1) To determine whether the baboon's thermoregulatory response to heat stress involves evaporative heat loss through either sweating or panting, or a combination of both; (2) to assess the effects of scopolamine on temperature regulation in the baboon; and (3) to obtain some indication of the similarity between the responses of men and baboons to heat and scopolamine.

The animals were tested in the climatic facility in a modified monkey chair. The measurements taken were total weight loss, weight loss from head sweating and exhalation, skin temperature, rectal temperature, heart rate, and respiratory rate.

In control experiments at 43°C (110°F) in which only saline was injected, body temperatures and respiration remained in equilibrium for 2.5 hours. The total weight loss amounted to about 180 mg/kg/min, whereas water was collected from the respiratory tract at a rate of about 30 mg/kg/min. In control experiments at 24°C (75°F), the body temperatures were lower and the total weight loss was only about 30 mg/kg/min.

Following intramuscular injection of scopolamine and methyl scopolamine in a 43°C (110°F) environment, total weight loss was reduced as much as 50% within 30 minutes, and respiratory rate and body temperature increased within 60 minutes. There was no substantial change, however, in the amount of water collected from the head and respiratory tract.

It was concluded that: (1) The baboon responds to heat exposure by an increase in body temperature and sweat production. In contrast to panting animals exposed to heat, the baboon obtains only a small fraction of its evaporative cooling from the respiratory tract. (2) Scopolamine and methylscopolamine inhibit sweating in the baboon. (3) In these respects the baboon resembles man.

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I. INTRODUCTION.

Funkhouser, Higgins, Adams, and Snow[1] investigated the responses of the baboon to heat and concluded that they were between those of the dog and man. They based their conclusions on (1) significant elevations of skin temperature, rectal temperature, and respiratory rate; (2) lack of statistical significance in the observed increase in oxygen consumption; and (3) the observation of sweating during exposure to heat. The questions left unanswered by their study are (1) does the baboon pant and sweat to regulate his body temperature, or is the increased respiratory rate similar to the hyperventilation observed in man;[2] (2) how would the animals respond if they were adapted to the test situation; i.e., if the intermittent struggling observed by Funkhouser et al. were reduced; (3) are the responses of an undrugged animal that has food and water available similar to those they reported; and (4) what are the quantitative values for evaporation caused by sweating and respiratory water loss?

Before any homology to man can be made, the heat responses of the baboon must be ascertained: If it has both mechanisms of evaporative cooling, will the blocking of one mechanism be compensated for by the other? Is the sweating of the baboon cholinergically controlled and thus manipulable by anticholinergic agents? In short, one must have quantitative data establishing a physiological homology before making assumptions and manipulating these variables to predict responses in man.

The present experiments were undertaken to examine the relations between evaporative cooling (separating sweating and respiratory water loss), body temperature, response to an anticholinergic agent, and adaptation to the testing procedures. The results can then be compared with results obtained under similar conditions in man.

II. METHODS.

The baboons (*Papio papio*), two female and one male, were approximately 2 years old at the start of the experiment and weighed 5.8 to 6.8 kg. They were housed in individual cages and had free access to food and water except during the experimental sessions.

Before the experimental session, the animal was confined in a restraining chair similar to the one described by Funkhouser et. al.[1] The plastic box that was placed over the head measured 17 by 25 by 27.5 cm and had two openings in the top, one for the entrance of air and the other for air withdrawal. Air was withdrawn at a rate of 10 l/min and passed through a tube containing 75 to 85 gm of silica gel. The desiccant tubes had a capacity to absorb approximately 8 gm of water vapor but were used to absorbing only between 1 and 2 gm.

After attachment of electrocardiograph leads and copper-constantan thermocouples (four on shaved areas of the back, stomach, and sides; and one 7-cm deep in the rectum), the animal, seated in the chair, was placed on a Buffalo platform scale in a room in which the temperature and humidity could be controlled. A pan of mineral oil was placed under the animal to minimize evaporization of urine and fecal water. (As the pan was also on the scale, the weight of the urine was a part of the total weight of the animal.)

Every 10 minutes two desiccant tubes were changed and the weight of the animal was recorded. The total weight loss was taken as an index of sweating, and the weight of the moisture collected in the tubes was a measure of water loss from the head sweating and from the respiratory tract. At the end of the experimental session, two or three 10-minute blanks were run; i.e., tubes of silica gel through which room air was passed. Thus the weight loss from the head and respiratory system was calculated by subtracting the average of the daily blanks from the figure obtained when the animal was in the apparatus. Blank size was approximately 0.6 gm/min. The periodic weight losses were divided by 10 and all weight loss data are expressed as milligrams per kilogram per minute.

Temperature was recorded every 5 minutes, and two readings were averaged to give the 10-minute reading to coincide with weight loss measurements. Skin temperature is the unweighted average of the four skin temperatures; and average body temperature, where used, is the sum of one-third of the skin temperature plus two-thirds of the rectal temperature. Respiration rate was recorded from a pressure transducer (Statham Labs No. P97TC) connected to the head chamber, and heart rate was obtained by counting the R waves in the electrocardiogram These measurements were made every 5 minutes, and two readings were averaged to give the 10-minute reading.

An experimental session consisted of 150 minutes in the climatic chamber. The first 30 minutes was considered to be equilibration, and weight readings were not taken. The next 60 minutes was the preinjection period, and the animals were kept in the test situation for 60 minutes following injection.

The drugs used in the present work were scopolamine hydrobromide, 5.2 and 6.9 μg/kg beq,* and scopolamine methylbromide, 5.0 μg/kg beq. These doses were experimentally established during the early portions of the study to allow independent assessment of the effects of heat stress and cholinergic blockade. The agents were diluted with sterile saline so that the volume of the injection was 0.5 ml. The injections were given to the thigh muscle, and at least 1 week intervened between tests to avoid drug interaction and acclimatization. Table I shows the order of treatments and the environmental conditions. The time between November and January was used for adapting the animals to the chair and headbox for 3 to 4 hours. (This was also the period when the drug doses were established.) The animals were put into the chair at least once a week and, if they were not tested in the climatic chamber, they were left in the chair in their home quarters for 3 to 4 hours.

During the acclimatization period the animals were exposed to a set of conditions similar to the ones used by Funkhouser et al.[1] which were 47°C (116°F) and 44% RH. These conditions seemed to be at the upper limit of temperature regulation for the baboons; as a result, the temperature for the main body of experiments in which the drug anhydrosis was tested was made a little less severe [dry bulb 43°C (110°F) and wet bulb 22°C (72°F)]. Methylscopolamine was used in one experiment to see if the quaternary compound caused a greater inhibition of sweating than did scopolamine hydrobromide. Upon completion of the drug experiments in heat, the baboons were exposed to a so-called "normal room temperature" of 22.8°C (73°F) to determine the responses of the now heat-stressed animal to the test situation.

An analysis of variance was done on the data from the main experiment, and although depicted in the figures as the mean for 30-minute blocks, the analysis was done on the scores for the individual 10-minute blocks.

*Doses are expressed in terms of the weight of the base.

Table I. Schedule of Treatment and Environmental Conditions

Date	Subject No.	Room temp				Treatment
		Dry bulb		Wet bulb		
		°C	°F	°C	°F	
5 Nov 68	2	46.6	116	34.4	94	None
6 Nov 68	1	46.6	116	34.4	94	
16 Jan 69	2	43.3	110	21.1	70	5.0 μg/kg MeScop.
16 Jan 69	3	43.3	110	21.7	71	
17 Jan 69	1	43.3	110	22.2	72	
7 Feb 69	1	43.3	110	22.2	72	0.5 ml Saline
14 Feb 69	2	43.3	110	22.2	72	
14 Feb 69	3	43.3	110	22.2	72	
27 Feb 69	2	43.3	110	21.7	71	5.2 μg/kg Scop.
27 Feb 69	3	43.3	110	21.7	71	
28 Feb 69	1	43.3	110	21.7	71	
6 Mar 69	2	43.3	110	22.2	72	5.2 μg/kg Scop.
6 Mar 69	3	43.3	110	22.2	72	
7 Mar 69	1	43.3	110	22.2	72	
13 Mar 69	2	43.3	110	22.2	72	6.9 μg/kg Scop.
13 Mar 69	3	43.3	110	22.2	72	
14 Mar 69	1	43.3	110	22.2	72	
10 Apr 69	3	43.3	110	23.9	71	0.5 ml Saline
11 Apr 69	1	43.3	110	21.7	71	
11 Apr 69	2	43.3	110	21.7	71	
17 Apr 69	2	43.3	110	24.4	76	6.9 μg/kg Scop.
17 Apr 69	3	43.3	110	24.4	76	
18 Apr 69	1	43.3	110	23.9	75	
8 May 69	1	22.8	73	14.4	58	None
9 May 69	2	22.8	73	15.6	60	
9 May 69	3	22.8	73	15.6	60	

III. RESULTS.

Figure 1 shows the results obtained for two animals under climatic conditions similar to those used by Funkhouser et al. [46.6°C (116°F), no injection].* The mean body temperature increased about 1C° in 40 minutes. Although there was an increase in water loss from the head and respiratory tract that accompanied the increased respiratory rate in the last segment of the experiment, the head and respiratory water loss accounts for only 1/14 of the total weight loss. At 30 and 50 minutes, the head and respiratory water loss was approximately 1/24 of the total weight loss. Although one of the animals was struggling during the last segment of the run, both subjects had a marked rise in body temperature at 70 minutes.

The results of the main set of experiments, conducted at 43.3°C (110°F), are presented in figures 2, 3, and 4; and table II summarizes the results of the analysis of variance of the data from scopolamine and saline. Because there was no significant difference between replications, the mean of the runs was used as the basic data unit.

The saline control data show that at an environmental temperature of 43.3°C (110°F), the baboon was able to maintain a constant body temperature, respiratory frequency, and weight loss; scopolamine inhibited sweating and thus caused a rise in body temperature (figure 5); the water loss from the respiratory tract and head was about 1/8 of the total weight loss, and there was no associated increase in water loss from the head and respiratory tract with increased respiration rate as measured here (figures 2, 3, and 4). Baboon No. 3 (figure 4) showed a greater rise in temperature when given 5.2 μg/kg than when given 6.9 μg/kg, whereas the total weight loss exhibited the expected dose-related depression. This animal seemed to be drowsy and sleeping during one of the 6.9 μg/kg runs. It should be noted that the day before the second 5.2 μg/kg run the animal escaped from its cage, and no small amount of excitement was generated by the process of capturing and returning the animal to his cage. He was jumpy and more reactive when tested the next day. The heart rates of the baboons were high and variable during the experiments.

Figure 6 compares the results of 5.0 μg/kg methylscopolamine with 6.9 μg/kg scopolamine (see also figure 5) and of "normal" room temperature with the saline data obtained at 46.6°C (110°F). It appears that 5.0 μg/kg of methylscopolamine produces a greater inhibition of sweating than does 6.9 μg/kg of scopolamine. From the 73°F data, it can be seen that the normal rectal temperature of the baboon is about 38.3°C (101°F); and in the hot environment, the rectal temperature regulates to around 39.0°C (102.3°F). An estimate of weight loss caused by insensible perspiration, respiration, and metabolism is 27.0 mg/kg/min, and the average respiration rate is 55.8 breaths/minute.

IV. DISCUSSION.

The results of the present study lead to the conclusion that the baboon responds to heat and scopolamine much as man does. In a hot environment, primary cooling in both species occurs by the evaporation of sweat with a relatively small contribution to cooling by respiratory water loss. This is in contrast to animals with few cutaneous sweat glands and in which a panting mechanism for heat loss has evolved. When exposed to heat and given scopolamine, both man and the baboon exhibit a decrease in sweating, an increase in skin temperature, and a subsequent rise in internal body temperature.

*All figures are based upon the data obtained at 10-minute intervals as presented in tables A-I through A-VI in the appendix.

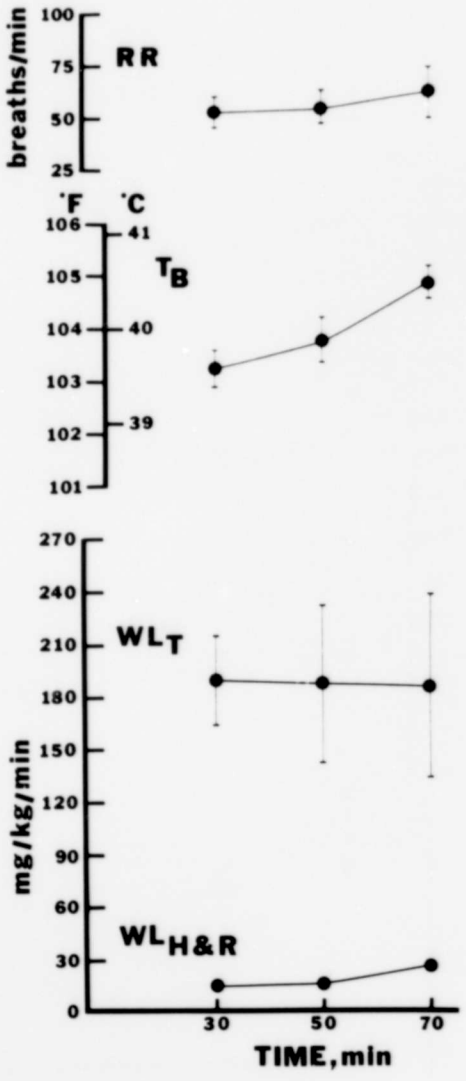

Figure 1. Mean Responses ±SE for Subjects 1 and 2 at 116°F

The variance was so small for the head and respiratory weight loss that it could not be plotted on the scale used. The mean plotted is the mean of the measures at the time plotted and the measures taken for the previous 10-minute period; e.g., the mean plotted at 50 minutes is the mean of the 40- and 50-minute periods. The data for this figure are contained in table A-I. RR = respiratory rate, T_B = average body temperature, WL_T = total weight loss, and $WL_{H\&R}$ = head and respiratory weight loss.

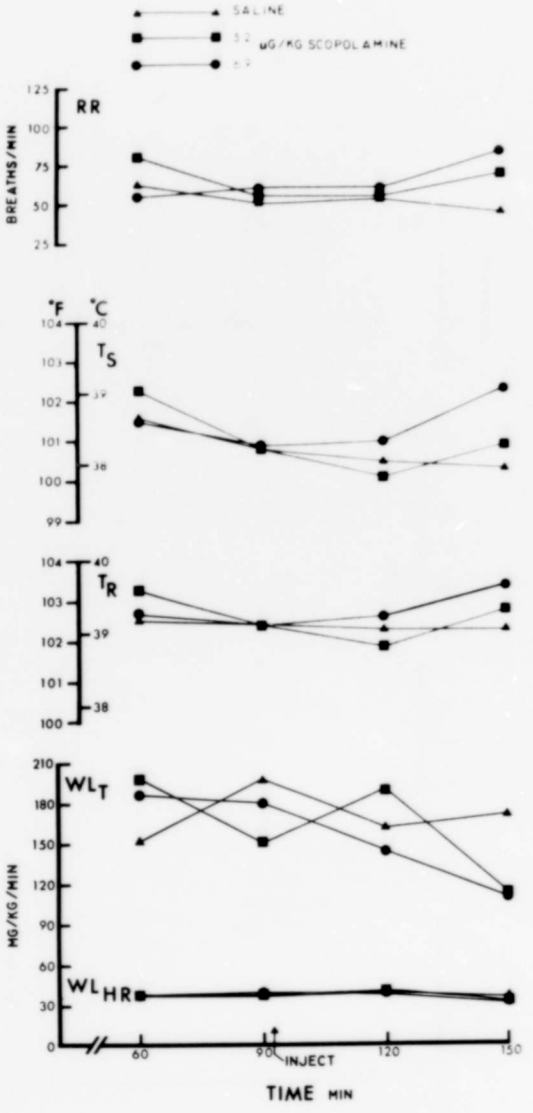

Figure 2. Responses of Subject 1 to Saline and Scopolamine at 110°F

Data are contained in table A-II. RR = respiratory rate, T_S = skin temperature, T_R = rectal temperature, WL_T = total weight loss, and WL_{HR} = head and respiratory weight loss. The 30-minute means are plotted at the end of the time interval; i.e., the 90-minute point is the mean of the observations taken at 60 and 90 minutes.

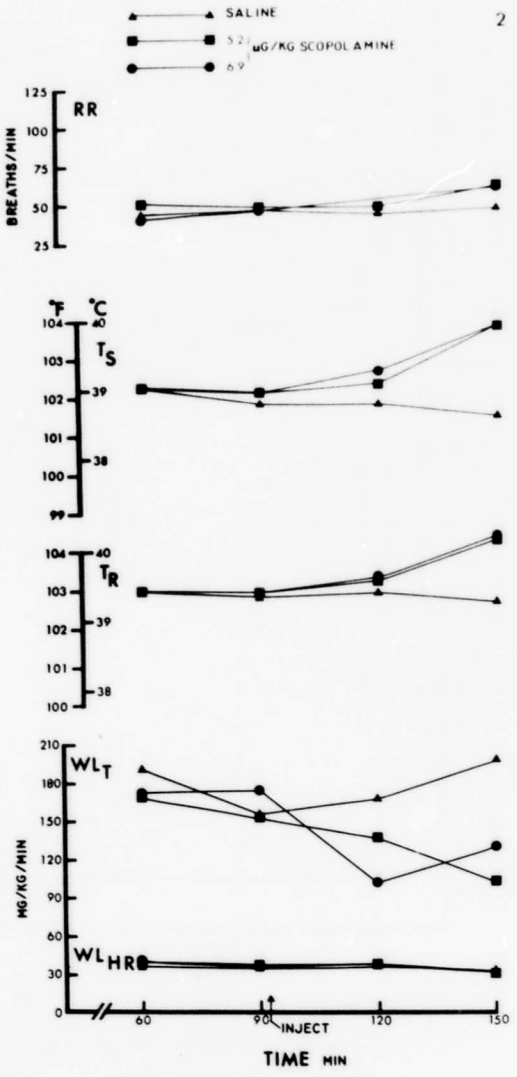

Figure 3. Responses of Subject 2 to Saline and Scopolamine at 110°F

Data are given in table A-III. Abbreviations and plotting protocols same as in figure 2.

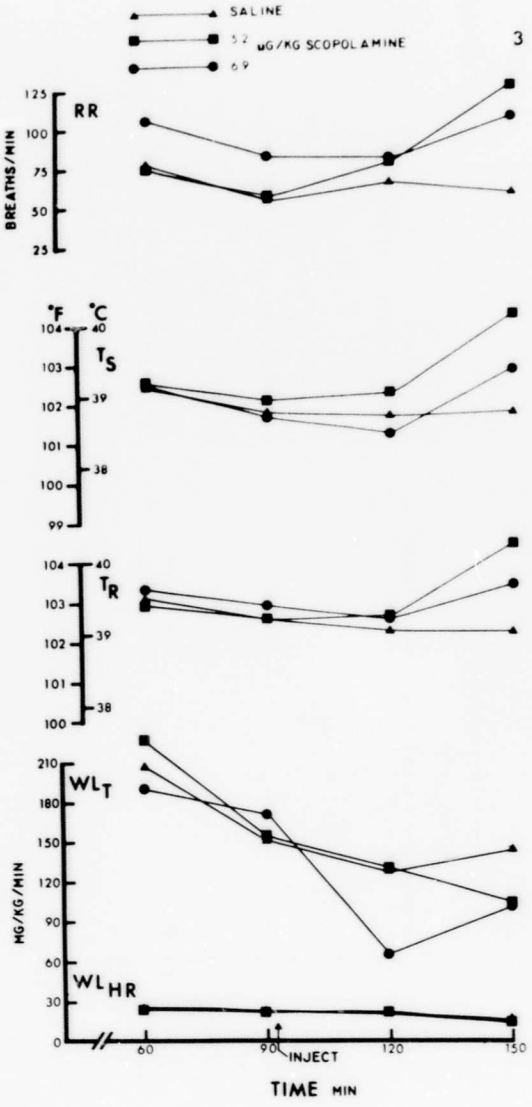

Figure 4. Responses of Subject 3 to Saline and Scopolamine at 110°F

Data are given in table A-IV. Abbreviations and plotting protocols are the same as in figure 2.

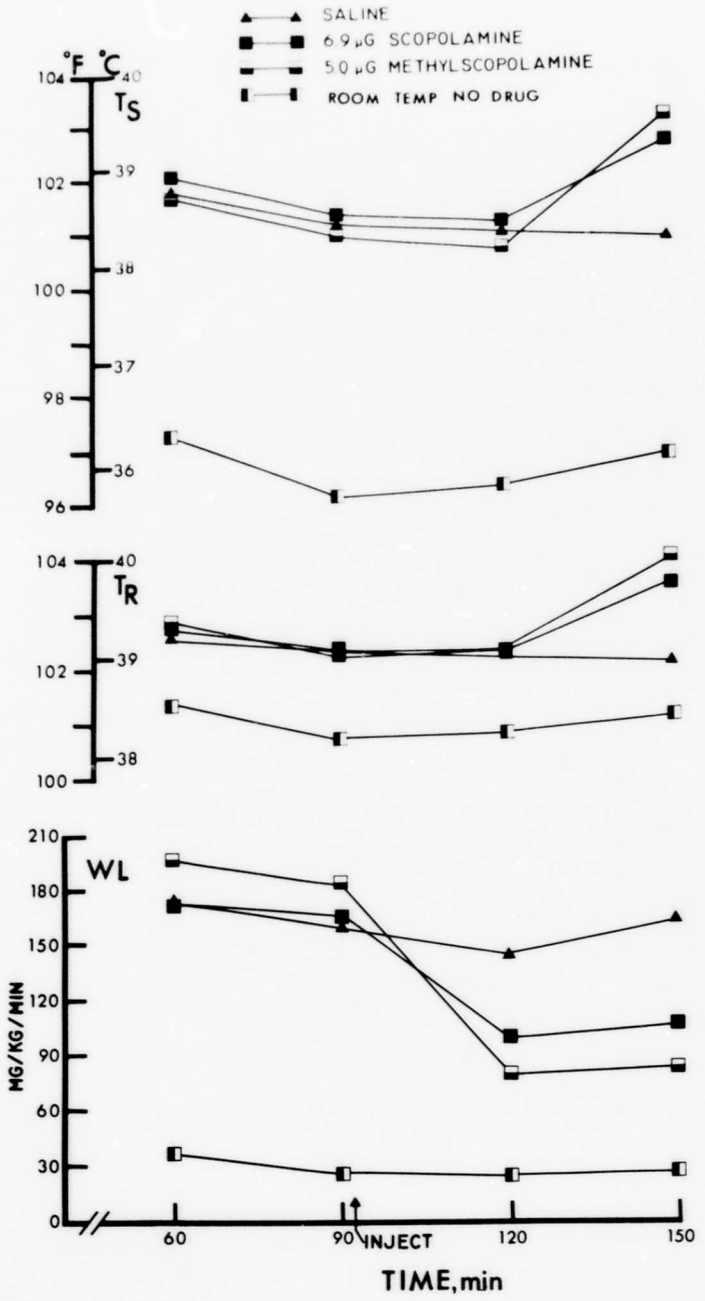

Figure 5. Summary of the Results for Scopolamine and Methylscopolamine at 110°F Illustrating the Ordering of Effect by Dose and Agent

Abbreviations same as in figure 1.

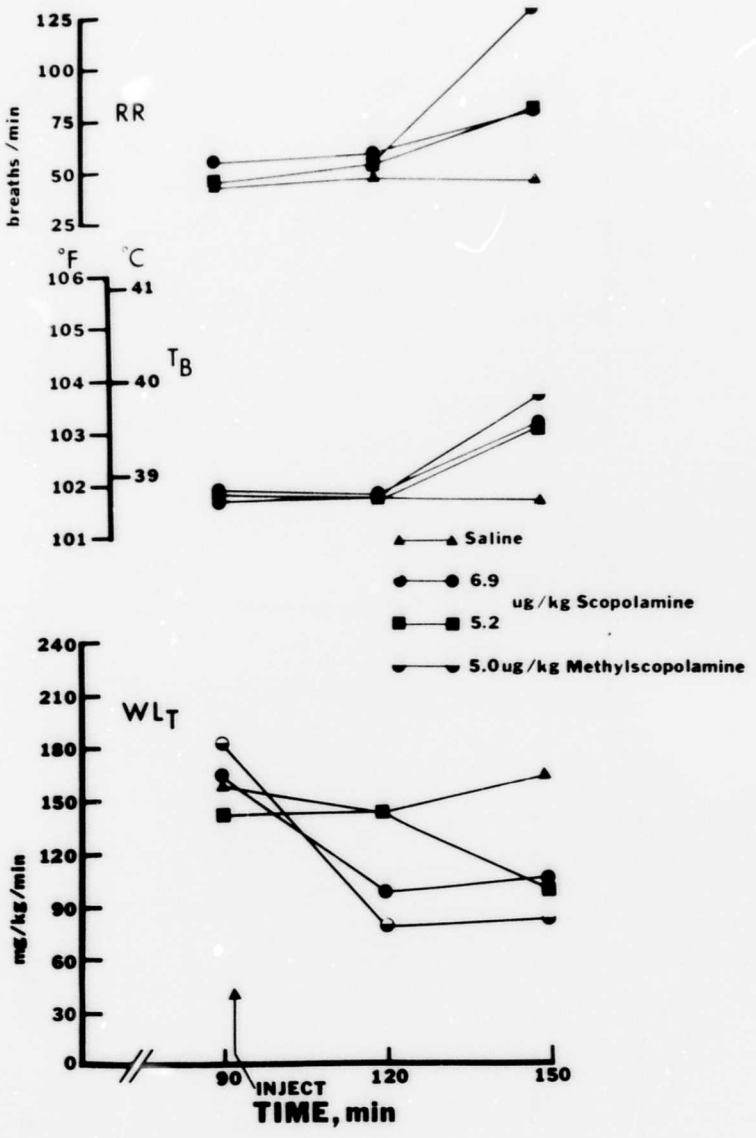

Figure 6. Mean Results for Scopolamine, Methylscopolamine (at 110°F) and "Normal" Room Temperature (73°F)

The means for methylscopolamine and 73°F are based on one run per animal per condition; whereas, the means for 6.9 μg/kg scopolamine and saline are for two runs per animal per condition. Data for methylscopolamine and 73°F are in tables A-V and A-VI. Abbreviations and plotting protocols are the same as in figure 2.

Table II. Significance of Analysis of Variance of the Data From Scopolamine and Saline

Variable	Replications	Drugs	Time	Drug × time
Total weight loss	NS	**	**	NS
Head and resp weight loss	NS	NS	**	NS
Rectal temp	NS	**	**	NS
Skin temp	NS	*	**	NS
Resp rate	NS	*	**	NS
Heart rate	NS	NS	NS	NS

NOTE: *p = 0.05; **p = 0.01; NS = not significant.

Though we have seen an increase in respiratory rate in response to heat, it is not accompanied by a significant increase in respiratory water loss and thus cannot be considered as panting. The maintenance of the rate of water collection from the head and respiratory tract after the injection of scopolamine could arise from the cancelling out of an inhibition of sweating from the skin of the head and an increase in water loss from the respiratory tract associated with the increase in frequency of breathing. An increase in ventilation rate in response to heat is well documented in man.[2,3] A closer look at the data presented by Funkhouser et al. reveals that with the increase in respiratory rate there is an increase in oxygen consumption. They indicate that the increase is not statistically significant. This may well be a result of an increased variability and not a lack of difference between means. Funkhouser et al. indicate that there was intermittent struggling during the tests; and, based on our relay experiments (before the animals were adapted to the procedure and chair), it is not at all surprising that the animals would increase ventilation as a response to activity (i.e., struggling) rather than for evaporative cooling. The respiratory rates measured in our baboons were close to double those reported by Funkhouser et al. The high respiratory and heart rates can be attributed to the youth of the animals. In addition, the experimental situation was one that lent itself to keeping the animals slightly agitated by periodic weight measurements, resulting in increases in respiratory and heart rate. Another possibility for the observed differences in basal respiratory rate is that both Funkhouser et al. and the authors they cite used some form of sedation either while the experiment was in progress or within 24 hours before the start of testing. If the ventilation rates thus observed in the present work are in fact "normal," then the low rates they observed are probably a manifestation of the sedation. If, on the other hand, the respiratory rates observed by Funkhouser et al. are "normal," the increase we observed may be attributed to the procedure and the initial struggle encountered while placing the animal in the chair.

The inhibition of sweating caused by methylscopolamine is considered to reflect the increased affinity of the quaternized forms of muscarinic drugs for muscarinic receptors.

Figure 7 shows the relationship between the baboons' responses to 6.2 μg/kg scopolamine in the present work and data on three human subjects from a report on the inhibition of

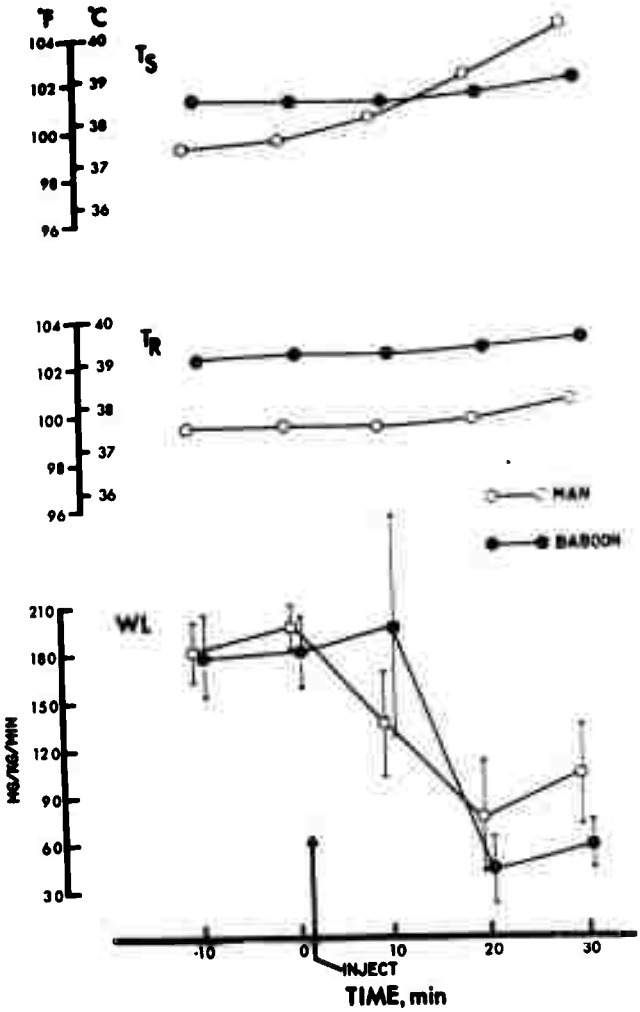

Figure 7. Comparison of the Responses of Man and Baboon to Scopolamine in a Warm Environment

120° and 124°F for the three men; 110°F for the two baboons. Abbreviations are found in figure 2. The baboon data are for 6.9 μg/kg from the present work and the source of the data for man will be found in the text.

sweating by scopolamine written by Craig, Cummings, and Sussman.[4] Two of the human subjects were exposed to 51°C (124°F), and the third to 49°C (120°F). The agent was administered by intravenous infusion over a period of 10 to 35 minutes and the average dose was 4.3 μg/kg. The weight loss data were divided by the subject's body weight times the number of minutes in the weighing period and expressed in milligrams per kilogram per minute.

The striking similarity of man and the baboon in regard to sweat inhibition and heat storage adds support to the proposal that the baboon be considered a substitute for man in the study of heat stress and muscarinic antagonists. Man's earlier rise in skin and rectal temperatures and earlier inhibition of sweating is attributed to the difference in route of agent administration (intravenous in man and intramuscular in baboons). In addition to the obvious differences in the two sets of data, it should be noted that air was being blown over the supine men, thus making evaporation and convection more effective,[5] while the baboons just sat in the restraining chair. The mean sweat rate of the baboons prior to injection was 179.41 mg/kg/min, and for man it was 188.25 mg/kg/min. The difference between the means is not statistically significant ($t = 0.47$, $df = 10$, $p < 0.05$). However, in a man under more similar conditions, seated in still air at 115°F, the rate would be down to 67 mg/kg/min.[6] A more adequate knowledge of the sweating capacity of the baboon would require observations of body temperatures and sweat rates under several environmental conditions so that one would determine the increase in sweat rate per degree increase in body temperature.

In spite of all the differences in technique and methodology, the data from man and baboon show a remarkable similarity, indicating that the physiological and pharmacological bases of thermoregulatory behavior may be the same for the two species.

V. CONCLUSIONS.

It was concluded that: (1) The baboon responds to exposure to heat by an increase in body temperature and sweat production. In contrast to panting animals exposed to heat, the baboon obtains only a small fraction of its evaporative cooling from the respiratory tract. (2) Scopolamine and methylscopolamine inhibit sweating in the baboon. (3) In these respects the baboon resembles man. The amount of training given the baboons in these experiments, however, was insufficient to enable them to endure exposure to heat passively.

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APPENDIX
RESULTS BY 10-MINUTE PERIODS

Table A-I. Results for 116°F, No Injection

Time	Weight loss*		Temp		Resp rate	Heart rate
	Head and resp	Total	Skin	Rectal		
min	*gm/10 min*		*°F*		*breaths/min*	*bpm*
Subject 1:						
10	0.297	-	102.8	102.6	69.0	185.0
20	0.498	11.0	102.7	102.7	72.5	195.0
30	0.515	10.0	101.4	103.0	50.0	161.0
40	0.545	3.0	101.7	103.2	45.0	156.5
50	0.374	14.0	102.3	103.7	77.5	208.5
60	0.507	15.0	103.0	104.8	90.0	207.5
70	1.146**	21.0**	104.2	106.4	-	-
Subject 2:						
10	0.415	-	104.1	103.4	40.0	190.0
20	0.503	7.0	102.8	103.8	39.0	185.0
30	0.361	14.0	103.5	104.3	47.5	215.0
40	0.548	13.0	103.6	104.9	43.5	220.0
50	0.856	12.0	103.8	105.3	50.0	212.5
60	0.866	3.0	104.2	105.7	47.5	217.5
70	-	9.0	104.4	106.0	40.0	195.0

*Weight of subject 1 = 5.4 kg, and subject 2 = 5.7 kg.

**15- rather than 10-minute reading.

Table A-II. Results for Subject 1

[For saline, scopolamine 5.2 μg/kg, and scopolamine 6.9 μg/kg. The data are the average of two runs under each condition. Environmental temp was 100°F]

Time*	Weight loss**		Temp		Resp rate	Heart rate
	Head and resp	Total	Skin	Rectal		
min	*gm/10 min*		*°F*		*breaths/min*	*bpm*
Saline:						
40	1.259	6.0	101.1	101.9	51.8	155.0
50	1.402	7.0	101.2	102.0	56.0	174.8
60	1.376	11.5	100.9	102.1	46.5	157.5
70	1.292	9.0	100.7	102.0	43.0	175.8
80	1.410	9.5	100.3	102.0	36.5	156.0
90	1.298	14.0	100.1	101.8	36.5	154.5
100	1.417	11.5	96.0	101.7	41.5	161.0
110	1.600	7.0	100.1	102.0	47.5	171.3
120	1.357	7.5	100.0	101.8	32.0	149.5
130	1.328	10.5	99.9	101.8	36.0	172.0
140	1.467	10.0	99.7	101.7	30.5	155.0
150	1.342	7.5	99.7	101.7	30.5	151.0
Scop.(5.2):						
40	1.534	9.5	102.2	102.8	73.5	187.5
50	1.617	14.5	101.9	102.8	68.0	188.8
60	1.288	8.5	101.3	102.7	64.8	173.3
70	1.516	10.0	100.8	104.8	45.3	173.0
80	1.264	6.0	100.2	101.9	41.8	165.3
90	1.330	8.0	99.8	101.5	41.0	153.5
100	1.558	15.5	99.7	101.4	52.0	180.0
110	1.334	10.5	99.5	101.4	35.5	159.5
120	1.420	5.0	99.7	101.5	41.5	153.8
130	1.050	5.5	100.1	101.9	48.2	160.8
140	1.174	5.5	100.2	102.2	53.8	163.8
150	0.986	6.5	100.7	102.6	67.2	161.8
Scop.(6.9):						
40	1.520	10.5	101.2	102.2	29.0	161.2
50	1.578	8.0	100.8	102.2	53.5	174.2
60	1.346	13.0	101.0	102.2	44.2	169.5
70	1.632	8.0	100.5	102.0	50.0	178.8
80	1.667	10.5	100.4	101.9	34.2	158.8
90	1.711	12.0	100.3	102.0	58.1	184.0
100	1.669	19.0	100.1	103.8	42.6	168.2
110	1.186	0.0	100.6	102.2	53.2	171.5
120	1.266	5.0	100.8	102.2	47.5	170.0
130	1.011	3.0	101.6	102.5	60.3	175.5
140	1.016	6.0	100.9	103.0	77.0	175.8
150	1.118	8.5	102.4	103.3	73.8	168.0

*Injections were given at 90 min.

**Body weights for saline runs were 5.9 and 6.0 kg; for scopolamine 5.2 μg/kg, they were 6.0 and 5.85; and for scopolamine 6.9 μg/kg, they were 6.1 and 6.25 kg.

Table A-III. Results for Subject 2

[For saline, scopolamine 5.2 μg/kg, and scopolamine 6.9 μg/kg. The data are the average of two runs under each condition. Environmental temp was 110°F]

Time*	Weight loss**		Temp		Resp rate	Heart rate
	Head and resp	Total	Skin	Rectal		
min	*gm/10 min*		*°F*		*breaths/min*	*bpm*
Saline:						
40	1.241	10.5	102.0	102.5	32.0	162.0
50	1.305	8.0	101.6	102.3	30.5	167.5
60	1.379	12.5	101.1	102.3	33.0	167.5
70	1.155	7.5	101.4	102.2	38.2	160.0
80	1.394	10.5	101.4	102.2	32.5	164.0
90	1.414	8.5	101.2	102.3	31.0	147.5
100	1.376	9.5	101.3	102.4	38.0	169.8
110	1.518	10.0	101.0	102.3	26.8	150.0
120	1.394	9.5	101.4	102.4	30.5	155.2
130	1.262	12.0	101.0	102.2	30.8	163.8
140	1.170	6.0	101.0	102.2	28.2	150.0
150	1.482	16.5	100.8	102.3	42.5	176.0
Scop.(5.2):						
40	1.505	9.0	101.9	102.5	36.2	190.8
50	1.426	10.5	101.7	102.4	36.0	190.8
60	1.506	9.5	101.5	102.3	33.0	186.2
70	1.316	8.5	101.8	102.4	34.5	173.5
80	1.518	10.0	101.5	103.4	33.5	177.0
90	1.588	8.0	101.4	102.4	37.5	187.8
100	1.507	9.5	101.6	102.5	31.2	178.2
110	1.737	9.0	101.4	102.6	35.0	152.5
120	1.314	5.0	102.3	103.0	40.5	159.5
130	1.212	2.5	103.0	103.5	44.5	173.8
140	1.086	6.5	103.3	103.8	46.2	161.8
150	1.317	8.0	103.4	104.0	54.0	163.8
Scop.(6.9):						
40	1.672	8.0	101.8	102.4	28.0	181.8
50	1.277	11.0	101.6	102.4	29.2	176.2
60	1.404	10.0	101.7	102.4	28.8	161.2
70	1.446	7.0	101.7	102.4	32.2	174.0
80	1.390	14.0	101.7	102.4	33.5	170.8
90	1.378	8.5	101.5	102.4	33.5	174.5
100	1.543	12.5	101.8	102.6	34.5	166.2
110	1.628	3.5	101.8	102.6	37.5	161.2
120	1.250	2.0	102.6	103.1	49.0	182.8
130	1.228	6.0	103.0	103.4	46.0	170.5
140	1.320	12.0	103.5	104.0	48.8	180.2
150	1.154	3.5	103.4	104.1	45.4	164.5

*Injections were given at 90 min.

**Body weights for saline runs were 6.4 and 6.15 kg; for scopolamine 5.2 μg/kg, they were 6.35 and 6.35 kg; and for scopolamine 6.9 μg/kg, they were 6.3 and 6.0 kg.

Table A-IV. Results for Subject 3

[For saline, scopolamine 5.2 μg/kg, and scopolamine 6.9 μg/kg. The data are the average of two runs under each condition. Environmental temp was 110°F]

Time*	Weight loss**		Temp		Resp rate	Heart rate
	Head and resp	Total	Skin	Rectal		
min	*gm/10 min*		*°F*		*breaths/min*	*bpm*
Saline:						
40	1.662	16.5	102.6	103.0	83.0	196.2
50	1.556	10.0	102.4	103.1	77.5	195.8
60	1.558	13.0	102.3	103.0	71.5	188.8
70	1.434	6.5	102.0	102.8	70.0	191.8
80	1.556	11.0	101.8	102.6	47.5	178.0
90	1.572	11.5	101.7	102.4	47.5	182.8
100	1.552	9.0	101.7	102.4	58.5	190.0
110	1.413	6.0	101.6	102.3	60.0	187.0
120	1.448	10.0	101.7	102.3	72.0	190.0
130	1.362	8.5	101.8	102.3	55.0	182.5
140	1.470	11.0	101.8	102.2	56.0	191.2
150	1.484	8.5	101.7	102.2	70.0	190.0
Scop.(5.2):						
40	1.548	12.5	102.5	102.9	71.5	175.8
50	1.564	12.5	102.4	102.8	64.0	177.8
60	1.615	16.0	102.5	102.8	85.5	182.2
70	1.257	9.5	102.1	102.6	57.0	178.8
80	1.758	10.5	102.2	102.6	54.5	173.8
90	1.464	9.0	102.0	102.5	61.0	185.0
100	1.754	12.5	102.2	102.5	63.5	188.8
110	1.611	8.5	102.0	102.7	70.2	172.0
120	1.380	4.0	102.6	103.0	99.5	192.5
130	1.162	5.0	104.1	104.0	115.0	211.2
140	1.238	7.5	104.4	104.8	144.5	195.0
Scop.(6.9):						
40	1.477	12.0	103.0	103.3	115.0	212.5
50	1.719	15.0	102.4	103.2	102.5	202.5
60	1.748	10.0	102.2	103.2	103.0	199.5
70	1.618	10.5	101.9	103.0	97.0	191.2
80	1.601	9.0	101.6	102.8	74.5	185.0
90	1.746	13.5	101.5	102.8	80.5	190.0
100	1.515	5.0	101.2	102.5	73.5	176.8
110	1.344	4.5	101.3	102.5	91.0	187.5
120	1.438	4.0	101.6	102.8	81.5	186.2
130	1.356	5.0	102.4	103.2	101.0	190.0
140	1.292	6.0	102.9	103.5	106.5	192.8
150	1.442	9.5	103.4	103.9	116.0	188.8

*Injections were given at 90 min.

**Body weights for the saline runs were 6.2 and 6.5 kg; for scopolamine 5.2 μg/kg, they were 6.25 and 6.4 kg; and for scopolamine 6.9 μg/kg, they were 6.25 and 6.82 kg.

Table A-V. Results for Methylscopolamine

[5.0 μg/kg; environmental temp was 110°F]

Time*	Weight loss**		Temp		Resp rate	Heart rate
	Head and resp	Total	Skin	Rectal		
min	*gm/10 min*		°F		*breaths/min*	*bpm*
Subject 1:						
40	24.3	122.8	101.2	102.6	36	170
50	25.7	157.9	101.3	102.0	32	150
60	30.6	105.3	101.2	102.3	48	170
70	25.9	122.8	101.1	103.0	33	155
80	30.6	140.4	100.8	102.2	42	170
90	25.9	105.3	100.4	101.9	36	170
100	30.2	175.4	100.2	102.2	36	167
110	27.8	40.4	100.2	102.0	34	150
120	31.3	122.8	99.3	102.6	100	230
130	26.8	122.8	101.9	103.8	114	210
140	27.8	52.6	103.2	104.8	142	270
150	28.2	140.4	104.9	107.6	140	310
Subject 2:						
40	34.9	274.2	102.2	103.6	58	230
50	24.9	241.9	101.8	103.4	54	210
60	29.0	258.1	100.9	102.4	48	210
70	27.3	338.7	100.6	102.0	36	190
80	23.4	129.0	100.2	101.5	46	210
90	30.3	64.5	100.5	102.2	56	230
100	28.1	129.0	100.3	102.0	31	160
110	24.9	64.5	100.0	102.0	28	210
120	17.1	112.9	100.0	102.4	32	210
130	19.2	48.3	100.7	102.0	58	240
140	20.7	64.5	101.3	101.3	80	250
150	20.2	96.8	102.7	102.7	102	300
Subject 3:						
40	27.8	-	102.4	103.2	54	180
50	27.6	-	102.0	103.0	84	190
60	27.8	-	101.6	102.6	44	165
70	24.3	161.3	101.6	102.5	40	167
80	29.5	193.5	101.6	102.2	52	180
90	25.2	112.9	101.2	102.2	62	190
100	27.6	32.3	101.6	102.4	47	160
110	26.9	64.5	101.8	102.4	80	240
120	23.9	64.5	102.6	103.0	94	240
130	21.0	64.5	103.5	103.8	156	235
140	32.8	32.3	104.1	104.4	206	280
150	18.1	112.9	106.0	106.0	190	265

*Injections were given at 90 min.

**Weight of subject 1 was 5.7 kg, subject 2 was 6.2 kg, and subject 3 was 6.1 kg.

Table A-VI. Results for 73°F, No Injection

Time	Weight loss*		Temp		Resp rate	Heart rate
	Head and resp	Total	Skin	Rectal		
min	*gm/10 min*		*°F*		*breaths/min*	*bpm*
Subject 1:						
40	21.8	64.0	97.9	101.8	76.0	168.0
50	15.2	32.0	96.0	101.0	105.0	187.0
60	14.3	48.0	95.9	101.0	90.0	192.5
70	14.7	48.0	94.8	100.8	65.0	209.0
80	18.1	0.0	94.1	100.4	54.0	161.0
90	12.9	32.0	94.5	100.4	62.0	162.5
100	12.8	48.0	94.6	100.4	55.0	172.5
110	10.3	32.0	95.2	100.4	54.0	161.0
120	5.1	16.0	94.9	100.4	72.0	167.5
130	10.4	32.0	95.1	100.4	48.0	163.5
140	10.1	48.0	95.2	100.5	63.0	171.0
150	8.7	0.0	95.4	100.6	60.0	160.5
Subject 2:						
40	17.2	33.3	97.9	101.4	-	182.5
50	-	33.3	97.5	101.3	64.0	201.5
60	-	16.7	96.7	101.0	65.5	190.0
70	11.3	33.3	96.5	100.8	47.0	197.5
80	-	33.3	96.2	100.6	43.5	184.0
90	-	16.7	96.0	100.4	36.0	153.0
100	-	16.7	96.6	100.6	48.5	195.0
110	-	50.0	96.7	100.6	45.5	175.0
120	-	0.0	96.8	100.8	58.5	186.0
130	-	0.0	97.2	101.1	37.0	185.0
140	-	33.3	97.2	101.2	43.5	174.0
150	-	16.7	97.2	101.2	44.0	191.0
Subject 3:						
40	-	58.7	97.6	101.6	59.3	195.0
50	9.22	14.7	97.6	101.4	44.5	179.5
60	9.25	14.7	97.6	101.4	42.5	172.5
70	8.52	0.0	97.6	101.2	41.0	173.5
80	-	44.0	97.6	101.3	43.8	181.0
90	-	14.7	97.7	101.2	74.5	209.0
100	-	0.0	97.8	101.2	50.5	190.0
110	-	29.3	97.7	101.4	41.0	185.0
120	-	14.7	97.7	101.4	60.5	200.0
130	-	14.7	97.9	101.6	44.8	190.0
140	-	44.0	97.8	101.6	50.0	186.5
150	-	44.0	97.8	101.5	51.5	200.0

*Weight of subject 1 was 5.8 kg, subject 2 was 6.4 kg, and subject 3 was 6.2 kg.

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13. ABSTRACT

The objects of this study were (1) to determine whether the baboon's thermoregulatory response to heat stress involves evaporative heat loss through either sweating or panting, or a combination of both; (2) to assess the effects of scopolamine on temperature regulation in the baboon; and (3) to obtain some indication of the similarity between the responses of men and baboons to heat and scopolamine. The animals were tested in the Climatic Facility in a modified monkey chair. The measurements taken were total weight loss, weight loss from head sweating and exhalation, skin temperature, rectal temperature, heart rate, and respiratory rate. In control experiments at 43°C (110°F) in which only saline was injected, the body temperatures and respiration remained in equilibrium for 2.5 hours. The total weight loss amounted to about 180 mg/kg/min whereas water was collected from the respiratory tract at a rate of about 30 mg/kg/min. In control experiments at 24°C (75°F), the body temperatures were lower and the total weight loss was only about 30 mg/kg/min. Following intramuscular injection of scopolamine and methyl scopolamine, total weight loss was reduced by amounts up to 50% within 30 minutes, and respiratory rate and body temperatures increased within 60 minutes. However, there was no substantial change in water collected from the head and respiratory tract.

14. KEYWORDS

Baboon	Sweating
Skin temperature	Homology
Rectal temperature	Average body temperature
Scopolamine hydrobromide	Heart rate
Respiratory rate	Respiratory water loss

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